Task 2.5 – Establish a program for post earthquake damage assessment

Description:

The team will establish a program by which information can be obtained from existing databases of structural performance. The team will extract relevant information and incorporate it into the study of component and system acceptability criteria. The program will be suitable to extend to future earthquakes, so that current information can continually be updated. The team will research existing building instrumentation efforts and identify knowledge bases that can be accessed to retrieve information. An effort will be made to identify means by which important ground motion information can be extracted from existing and future earthquake records.

Personnel: Design professionals, Government agencies, Researchers, Earth sciences community

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 2.6 – Prepare documents and reports for use in PBSD Guidelines

Description:

This task will occur at milestones within the research plan developed in Task 2.1.2 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the RMP and NPP will occur to insure that information is presented in a consistent manner. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 2.1.2 to set out the goals for the next phase of research.

Personnel: Engineers, Researchers, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Challenges

The following list of issues will certainly not encompass all the challenges surrounding the development of the **SPP**, but they should be made a special focus of the development teams.

- *Analysis and modeling*

  It will be important to identify techniques for analysis that can be applied by a broad spectrum of engineering offices. Different methods will need to be calibrated so that results are consistent. Modeling procedures, especially nonlinear methods, will require that software be developed that most designers can obtain and use with reliability and consistency. Academic research has to be translated into formats that can meet the budget and scheduling constraints of design professionals. It may be advisable to collaborate with software houses to develop programs or algorithms based on the procedures.

  Developing consistent approaches for new and existing buildings will also be a challenge.

- *Ground motion*

  Engineers must be able to obtain reliable ground motion information to reduce uncertainty in PBSD design. Error in ground motion assumptions, common in current practice, can quickly overshadow the increased accuracy of the design methodologies. Nonlinear time history analysis has the potential to play a significant role in PBSD. Therefore, procedures for obtaining a robust suite of records suitable for individual sites will be an important part of the overall effort. Understanding the interaction of earthquake sources, travel paths, the site and the structure will also be a difficult challenge.

- *Performance levels and damage states, Acceptability*

  Developing performance indices that are valuable to building stakeholders will be a crucial first step. Engineers may face the challenge of having to develop very specific performance levels and damage states to meet owners' needs.

  Translating elemental damage into global damage will require review of past efforts, research and perhaps significant modeling studies.

- *Reliability*

  Quantifying reliability and uncertainty in component behavior will be a challenge due to the relatively small amount of data from past earthquakes and testing. It will also be a challenge to develop reliability methods that can be adopted and applied by design professionals.

- *Data Acquisition*

  Developing a program for extracting performance data from past and future earthquakes will be a logistical and financial challenge. It will take discipline to maintain the program that is established and to make use of the data that are obtained.

PRODUCT 3 - Nonstructural Performance Products

These products will form an important reference component of the PBSD guidelines. They will include information similar to that developed in the Structural Performance Products, but relating to nonstructural building components. They will also include the following concentrations:

- *Prediction of the demands on nonstructural components and the evaluation of their performance under these demands.*

  Just as forces on a structure are developed due to ground shaking and are affected by the interaction between the soil and the structure, nonstructural component demands are developed due to the building shaking and are affected by the interaction between the structure and the components. It will be necessary to study and develop methods by which these demands can be predicted. It will also be important to develop techniques for evaluating the performance of the components under these demands.

- *Testing and certification programs to bring uniformity to the design of manufactured components.*

  More so than buildings, modeling of nonstructural performance is difficult at best and needs to be supplemented with testing. The testing program will have to be broad enough to account for the placement of equipment and contents in different areas within various building types. It will also need to allow certification of equipment and contents bracing for an expected performance objective.

- *Post-earthquake data acquisition and analysis.*

  A detailed plan is needed for acquiring and analyzing performance data from future earthquakes. The nature of this data needs to be defined. Following a major earthquake, the data will be processed and compared to the Guideline provisions. The Guidelines will be modified in future editions by using lessons learned from performance of nonstructural components. This program is considered optimal for the effective development of PBSD.

- *Evaluation of nonstructural components in existing buildings*

  In addition to developing procedures for the installation of nonstructural elements in new buildings, it will be important to devise methods for assessing and increasing the performance of components already installed within existing buildings.

The nonstructural performance products will be developed by a team of design professionals, scientists, equipment manufacturers and researches expert in the behavior of nonstructural components. Testing agencies will be employed as part of the certification program. User groups will be brought in to develop goals and strategies and to assist in the verification process.

Successful development of the NPP will require outside funding of testing. A comprehensive program will cost millions of dollars and will be an ongoing effort. Funding identified herein must be augmented by research dollars provided by industries and manufacturers which have a stake in the performance of nonstructural systems.

Task 3.1 Identify initial parameters and current state of the art

Task 3.1.1 – Identify nonstructural components and their impacts on performance

Description:

The team will identify the various types of nonstructural components and systems that are vulnerable to loss. It will utilize existing efforts in this area. In addition to looking at individual components, a goal will be to understand how the components fit together into systems (i.e. pumps and fans are parts of a chiller system), and what the effects of damage to one component means to the system. Identifying weak links in systems is important. The team will then identify what systems are typically present in various building types, and what the weak links are when considering overall building performance.

Another focus of this task will be to identify the scope of the Nonstructural Performance Products. The team will determine the detail with which issues of design, installation and maintenance of nonstructural components will be evaluated.

Personnel: Design professionals, Material suppliers, Owners

Priority: Essential
Budget: $250,000
Duration: 2 years

Task 3.1.2 – Evaluate effectiveness of current nonstructural and contents installation standards and practice

Description:

With the list of components and systems from task 3.1.1, the team will identify information on performance in past earthquakes. It will catalogue and quantify performance of components and systems by themselves and in relation to overall building performance, in terms of capital and contents loss and down time. The team will compare the effectiveness of different designs of the same components. Issues which play the greatest role in performance will be prioritized (i.e. anchorage design vs. installation quality, equipment ruggedness, etc.). A goal will be to assess the current state of the art and identify gaps in existing knowledge.

Personnel: Design professionals, Material suppliers (Researchers, Owners)

Priority: Essential
Budget: $300,000
Duration: 2 years

Task 3.1.3 – Develop a research plan to advance the state-of-the art

Description:

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Researchers, Design professionals, Material suppliers

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 3.2 – Develop analysis and design methodologies

Task 3.2.1 – Quantify nonstructural performance levels

Description:

Working with the performance definitions developed in the **SPP**, the team will quantify nonstructural performance levels using appropriate parameters (drift, damage, loss, business interruption, casualties, etc.).

The goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in later tasks can be targeted to definitive numerical quantities.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $350,000
Duration: Throughout the project

Task 3.2.2 – Develop demand prediction methodologies

Description:

The team will develop processes to calculate the demands on nonstructural components based on their location within various building types. It will identify and describe in measurable terms the parameters that have the most important effects on these demands (height above grade, building stiffness, anchorage, etc.). The goal is to be able to extrapolate from the basic building acceleration, velocity and displacement characteristics, the effects on nonstructural components.

Personnel: Design professionals, Material suppliers, Researchers

Priority: Essential
Budget: $450,000
Duration: Throughout the project

Task 3.2.3 – Develop analytic methodologies for achieving performance levels

Description:

The team will fill in the gaps in existing knowledge identified in earlier tasks. Research will consist primarily of analytical efforts. The team will identify promising new techniques and devote research to making them applicable to the PBSD framework. A forum will be held, bringing together design professionals and manufacturers to discuss design and analysis methodologies.

Following this, a strong effort will be made to develop design and analysis methodologies, consistent with the efforts in the **SPP**.

A focus will be on developing modeling or other techniques to lend consistency to design and analysis. Modeling will account for the range of computer applications currently available and anticipated in the future. It will also account for the financial investments various design engineers are able to make in obtaining modeling technology.

Personnel: Design professionals, Researchers, Material suppliers (Government agencies)

Priority: Essential
Budget: $850,000
Duration: Throughout the project

Task 3.2.4 – Coordinate design and analysis methods with SPP

Description:

The team will compare the design and analysis methods of the **SPP** and **NPP** to ensure that they are compatible and that they lead to the same measures and prediction of performance. The team should check that the level of reliability is similar between the two and that structural and nonstructural performance measures can be combined to form overall performance goals for buildings. The team will also make a focused effort to describe the functions of the **SPP** and **NPP** in relation to the overall goal of PBSD and of the guidelines. A task will be to describe building behavior from both points of view in technical and financial terms and identify where structure and nonstructure overlap or come in conflict.

Personnel: Design professionals, Researchers, Material suppliers

Priority: Essential
Budget: $150,000
Duration: Throughout the project

Task 3.3 – Establish separately funded testing and data collection programs

Task 3.3.1 – Establish comprehensive testing and certification protocols

Description:

The team will catalogue all relevant testing information to date. It will identify gaps in this knowledge with respect to nonstructural component effects on building performance. Research programs will be developed and established to fill these gaps.

A distinction will be made between component "ruggedness:" the ability of the piece of equipment to stay together in a functional black box, and "anchorage:" the ability of the equipment to remain where it was installed.

The team will identify *sources of funding* for extensive testing. These sources will include equipment manufacturers, owners, insurers, government agencies, etc. This may include developing collaborative efforts between equipment buyers and equipment manufacturers, for example. The team will develop a consensus on the technical description of testing protocols. The team will develop a means of obtaining certification of tested equipment for various seismic regions, building types and usage, and locations within buildings. If financially feasible, some testing should be conducted within this task to calibrate certification parameters.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal (does not include funds for extensive testing)

Budget: $1,000,000

Duration: 5 years

Task 3.3.2 – Establish a post-earthquake data collection and analysis program

Description:

The team will *establish* a program for collecting nonstructural performance information after an earthquake. This will be coordinated with the efforts in the **SPP**. Existing earthquake performance data will be reviewed for its usefulness and as appropriate will be assembled and catalogued into a database. The team will develop ways to distill and use this information and identify where gaps remain. A workshop will be held to identify the types of information that are the most valuable. The team will develop data collection forms, binders, instructions and databases in preparation for use. It will establish a methodology for creating and maintaining a team of inspectors and will hold seminars on a regular basis to train them. A focus will be to identify how the collected information will be used within the development and refinement of the PBSD Guidelines. The team will identify sources of funding for post-earthquake data collection, so that these groups may be approached in a timely fashion after a damaging event.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Optimal
Budget: $300,000
Duration: 2 years

Task 3.3.3 – Establish a program for developing innovative nonstructural design

Description:

The team will *establish* a program for encouraging manufacturer's to develop innovative nonstructural designs that take advantage of the performance-based criteria developed within this project. The team will identify sources of funding to implement this program. Implementation will include offering incentives for use, marketing the program and tracking its success.

Personnel: Design professionals, Material suppliers, Owners, (Government agencies)

Priority: Optimal
Budget: $300,000 (includes only the establishment of the program framework)
Duration: 1 year

Task 3.4 – Develop documents and reports for use in PBSD Guidelines

Description:

This task will occur at milestones within the research plan developed in Task 3.1.3 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **RMP** and **SPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team of Task 3.1.3 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  Developing modeling and analysis techniques for nonstructural systems will be a very challenging effort. The complexity of these systems may overwhelm the capacity of most office computer systems. Reliable methods for estimating the performance of these elements, however, is vital to reaching higher levels of overall building performance. As with the **SPP**, software engineers may need to be consulted and retained to develop programs which can model piping, equipment, ducts, and other elements which have the potential to cause significant loss.

- *Performance levels and damage states*

  Understanding a component's anchorage to the structure is only one half of the challenge of nonstructural systems. Being able to reliably estimate the "ruggedness" of the piece of equipment is also important. A major effort will be required of design professionals and equipment manufacturers to find ways to define equipment fragility and to test for and design ruggedness into equipment.

- *Administration*

  Peer review and plan check of equipment anchorage is a novel concept and will need acceptance from building officials. This will require a major effort to write provisions for their use and to educate and train them on the subject.

- *Education and Incentives, Cost*

  Full scale testing of equipment will prove to be a monumental and very expensive effort that will require funding from multiple sources. Convincing owners and manufacturers to pay for this testing will be a challenge.

  With the idea of certification of equipment will come issues of liability for performance. It will be difficult to convince manufacturers to warrant their equipment and contractors to be responsible for installation. Owners may be able to provide incentives to convince these stakeholders that certification is in their best interests.

- *Data Acquisition*

  As with the **SPP**, similar challenges will be faced in obtaining useful information and maintaining the data collection program.

PRODUCT 4 – Risk Management Products

These products will provide financial information for the Stakeholders' Guide and the PBSD Guidelines. The goal will be to identify cost-benefit and other models by which PBSD can deliver the most benefit to the users. The products will have three main areas of focus:

- *Methodologies for quantifiably defining performance objectives in terms of expected loss, risk and stakeholder tolerance.*

  The work will utilize the efforts of the **SPP** and **NPP**. It will consider issues of damage costs, loss of operation, risk tolerance, etc., with the expectation of obtaining realistic design goals for stakeholders.

  Minimum performance objectives will be established, considering the broader social and economic drivers that affect planning, design and construction decisions. An effort will be made to consider the effects on building performance of elements outside the building envelope, such as infrastructure, utilities and other lifelines.

- *Identifying and minimizing uncertainties in the PBSD process.*

  A key to obtaining wide use of PBSD is developing more reliable and accurate analysis and design methodologies. Uncertainties, error and randomness must be related numerically through reliability measures to the methods developed in the **SPP** and **NPP**. Ways need to be found to minimize these sources of inaccuracy. Risk associated with building performance should be quantified in relation to other activities (such as fire, building maintenance, revenue, etc.). Methods for more accurately identifying risk and reaching acceptable risk levels need to be developed.

- *Developing cost/benefit and other financial analysis models.*

  The philosophy behind PBSD centers on being able to choose from a range of performance objectives, to reliably meet the financial goals and risk tolerance of the stakeholders. Techniques for determining and optimizing cost-benefit ratios and other financial representations of construction are important to achieving implementation. Non-engineering groups need to have a complete understanding of PBSD and its benefits. It is also important for design professionals to understand the concepts of risk management.

  An effort will be made to emphasize the broader global planning opportunities that PBSD presents for reducing economic and social losses to communities, regions and states. The RMP should provide the basis for economic and social rating systems for buildings.

Task 4.1 – Quantify performance objectives

Task 4.1.1 – Match performance levels with hazards to develop performance objectives

Description:

The team will take the performance levels and hazards developed in the **SPP**, **NPP** and **RMP** and combine them in order to understand expected performance over measurable and meaningful timespans (building life, a typical mortgage, careers, etc.). The team will select performance objectives for various building types, occupancies, construction eras, etc, and develop performance expectations for these buildings over their lifetimes. A focus will be to define the goals that owners and design professionals can utilize for capital planning and design purposes.

Personnel: Design professionals, Researchers, Owners, Financial interests

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.2 – Develop minimum performance objectives considering social and economic drivers

Description:

The team will identify the various social and economic drivers that affect decisions about designing to a particular performance objective. The team will evaluate issues of cost, safety, construction duration, building function, etc. and will consider how each affect the various stakeholders. The goal will be to establish a set of minimum performance goals that protect the interests of all the parties involved in the building environment and provide for the protection of the public welfare. The team will discuss minimum performance standards for external elements that affect building performance, such as infrastructure, utilities and lifelines.

Personnel: Design professionals, Researchers, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $350,000
Duration: 1 year

Task 4.1.3 – Quantify performance in terms of loss and risk

Description:

The team will develop a set of acceptable risk levels quantified in terms of loss (capital, lives, down time, etc.), considering building type, usage, age or other parameters. It will link performance objectives with these acceptable risk levels. Risk will be defined in agreed upon terminology with varying levels of reliability. The team will define a set of maximum loss thresholds for each performance objective. The Stakeholders' groups will be tapped to provide input. A methodology will be developed to convert loss into financial terminology.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Other stakeholders)

Priority: Essential
Budget: $400,000
Duration: 4 years

Task 4.2 – Develop financial modeling tools

Task 4.2.1 – Develop a research plan to advance current risk evaluation methods

Description:

The team will gather existing information on risk analysis and financial modeling methods and identify gaps in current knowledge. A strong effort will be made to use available information so that future research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort.

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Financial interests, Researchers (Design professionals, Owners)

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 4.2.2 – Develop financial life cycle and damage cost models

Description:

The team will use the structural and nonstructural performance acceptability criteria in the **SPP** and **NPP** to calculate life-cycle and annualized losses relative to each performance objective. Combinations of performance objectives will be evaluated to help users minimize overall life-cycle and damage costs. The team will extrapolate costs for individual buildings, to look at classes of buildings and regional implications for cities, states and the federal government. Costs of repair, business interruption and casualties will also be developed. The goal is to quantify expected losses in a manner that stakeholders can use in long term capital planning. Example applications will be developed. The information developed within this and other tasks should also form the basis for building rating systems, which will integrate structural and nonstructural quality with financial and social performance measures.

Personnel: Researchers, Financial interests, Owners, Government agencies

Priority: Essential
Budget: $650,000
Duration: Throughout the project

Task 4.2.3 – Define cost-benefit relationships for improving performance

Description:

The team will develop tools by which the costs of different retrofit measures (existing buildings) or design criteria (new buildings) can be weighed against the expected reduction in loss and life-cycle costs. A comparison of individual components will be necessary (such as bolting down a wood building vs. bracing sprinkler pipes). The combination of components into design systems will also be considered. Cost-benefit relationships need to be developed in ways that can be calculated by design professionals and are meaningful to owners and financial interests. Cost-benefit ratios should be applicable to individual buildings or portfolios. The goal should be to provide owners with methods for performing economic loss management of their facilities. Efforts will be made to look at how this can be expanded to a regional basis.

Personnel: Design professionals, Researchers, Financial interests, Owners, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.2.4 – Calibrate financial models

Description:

The team will develop a series of example applications and will calibrate and compare them against current design techniques. Calibration parameters will include cost, duration, responsibility, liability, etc. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed. The team will develop methodologies to project costs and other data into the future. In this way, the information can function as a capital planning tool.

Personnel: Design professionals, Researchers, Financial interests

Priority: Essential
Budget: $500,000
Duration: Throughout the project

Task 4.2.5 – Develop cost-effective design strategies

Description:

With information from previous tasks the **SPP** and the **NPP**, the team will develop strategies to improve performance based on building class, usage, location, etc. The team will consider components and systems, identifying which individually and which combinations typically will provide the minimum expected life-cycle cost involving tradeoffs between the initial cost and potential damage costs. The information will be presented in a manner that is usable by engineers for design and will give owners and financial interests a numerical valuation of the money spent. The team may use information obtained in past earthquakes, coupled with testing research previously done.

Personnel: Design professionals, Researchers, Financial interests, Owners

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.3 – Educate users about risk management concepts

Description:

The team will establish a program to teach stakeholders about risk management. Representatives of lending agencies, insurance and financial institutions and researchers will write papers and create tools to apply the concepts developed in the above tasks. The team will hold workshops and seminars to discuss this information. The goals for design professionals, contractors, material suppliers and building officials are to recognize that PBSD involves choices about risk, and to be able to use the risk management tools provided in the Guidelines. For building owners, the goal is to bring awareness of how these tools fit in with current risk management techniques they use when purchasing space, making renovations, considering deferred maintenance, etc. A strong effort will be made to identify ways to coordinate current risk analysis techniques used by owners and financial institutions (probable maximum loss, ratings, etc.) with these new tools.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $500,000
Duration: Throughout the project

Task 4.4 – Identify legal implications of PBSD

Description:

The team will contract with attorneys to address the legal implications of moving towards PBSD oriented building codes. The team will develop a list of issues that need to be evaluated, including: liability in the event of unexpected performance, cost allocation, long-term responsibility for the building or components, definitions of terms such as “significant,” “reliable,” etc. The goal will be to develop strategies to make

PBSD more attractive to stakeholders from a legal standpoint.

Personnel: Attorneys, Design professionals, Financial interests, Owners, Building officials, Government agencies

Priority: Optimal
Budget: $250,000
Duration: 2 years

Task 4.5– Develop documents and reports for use in PBSD Guidelines and Stakeholders' Guide

Description:

This task will occur at milestones within the research plan developed in Task 4.2.1 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the **SPP** and **NPP** will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 4.2.1 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Government agencies)
Priority: Essential
Budget: $400,000
Duration: Throughout the project

Challenges

- *Analysis and modeling*

  A major effort will be required to develop financial tools relating costs to structural and nonstructural performance. This will require close collaboration between design professionals and Financial interests.

- *Acceptability*

  It will be important to define acceptable risk. The challenge will be in quantifying stakeholders' tendencies to be either risk adverse or risk tolerant. A key to successful implementation of PBSD is the ability to match a design with the owners' risk tolerance.

  Considering broader social and economic factors affecting a building -- such as a hospital remaining functional to treat injuries within the community, or even of a grocery store being able to provide emergency food supplies after a damaging event -- will complicate the consideration of minimum performance objectives and liability.

- *Data Acquisition*

  A challenge will be to obtain useful information on performance versus loss and performance versus design and construction costs. A major effort may be warranted to cost estimate example designs using the PBSD procedures. This information will be needed to calibrate cost models.

- *Reliability*

  Identifying uncertainties in quantifying costs, damage, hazard and risk will be a major challenge. New methods for integrating engineering design and analysis with financial and social modeling will need to be developed and tested.

PRODUCT 5 – PBSD Guidelines

The Guidelines form the most important product resulting from this project. They distill the information developed in the **SPP**, the **NPP** and the **RMP** into the application document used by design professionals, manufacturers, government agencies and building officials in design and construction. These guidelines can form the basis for the next generation of building codes and earthquake resistant design practice. When implemented, these guidelines should permit economical design that can reliably attain desired seismic performance.

The Guidelines will have to be broad in scope yet deep in level of detail. They need to be usable by a wide range of design professionals. They will focus on:

- *Selecting and quantifying performance objectives, including cost performance.*

  A set of consistent performance levels for new and existing buildings is essential. To be useful and reliable, predictors of structural and nonstructural performance must be characterized in a manner that can be understood by building owners.

- *Defining minimum and standard performance objectives.*

  Although the concept of performance based design permits owners to specify custom objectives for each building, presumably codes will need to have a single set of minimum and standard objectives used for enforcement purposes. These will need to be defined and incorporated into the performance objectives. They should be based on considerations of acceptable risk and should be based on input from multiple stakeholders. In addition, the desired reliability level in achieving these objectives needs to be specified.

- *Characterizing performance and hazard levels consistent with the objective.*

  The performance objectives must be quantified in engineering terms. This includes defining specific acceptable damage levels for various elements, both structural and nonstructural as well as permissible global behavior of the structure itself. Characterization of ground motion will also be important.

- *Performance prediction and evaluation methods.*

  The methods in the guidelines will facilitate design of structures of any configuration for any desired performance and can be used to calibrate building codes for new buildings or develop new codes. Methodologies used for evaluation and retrofit of existing buildings can also be calibrated. Lastly, the financial industry can use the guidelines as a basis to develop methods of ranking the design performance of buildings for underwriting purposes.

- *Means of verification.*

  The various analytical procedures used to evaluate performance and demonstrate acceptability, together with suitable modeling rules and prescriptive requirements on configuration and detailing must be verified. The uncertainty inherent in each of these procedures for buildings of different sizes, types, and configurations, and for different performance levels must be quantified. While a minimum level review is essential, a broad program of verification will be optimal.

- *Procedures for installing and maintaining nonstructural components and contents in buildings.*

  This information will focus on the issues related to installation and maintenance of nonstructural components. Not least among these is the division of responsibilities and liability between the component manufacturer and installer. As the design engineer observes building construction, equipment installation should also be observed for compliance to the manufacturer's specifications.

- *A technical commentary serving as backup for the Guidelines.*

  No matter how well stated in the PBSD Guidelines, the rationale and history behind the provisions will be subject to the interpretation of the engineers and building officials employing them. A comprehensive commentary is necessary to give these users a fuller picture of PBSD and direction when implementing it. The commentary should also include a series of example applications of the guidelines.

The Guidelines will involve major participation from all stakeholders, including design professionals, researchers, manufacturers, owners, financial institutions, building officials and governing agencies. A comprehensive program of verification will require input and involvement from a broad range of users. Technical writers and code officials will also be employed to produce the highest quality document.

The guidelines will be developed in phases. The first, or the 25% phase, will include a basic framework for the Guidelines, to be filled in with research and tools from the **SPP, NPP** and **RMP**. Review by the Guidelines teams at this stage will focus on refining or changing the direction of the technical research efforts for these products. The next phases at 50% and 75% will continue to take information from the technical products and flesh out the Guidelines, again returning comments to refine the research. The 100% phase will consist of final review, formatting, wordsmithing and publication. An important task within the Guidelines product is to develop this phasing further and to coordinate overall efforts with the steering committee.

Task 5.1 – Reach consensus on Guidelines format and development process

Description:

The main goal of this effort will be to reach a consensus on the format of the Guidelines, and to develop a conceptual framework. The team will also establish a procedure for taking the information from the **SPP, NPP** and **RMP** and writing the guideline provisions.

Personnel: Design professionals, Researchers, Material suppliers, Contractors, Financial interests, Owners, Building officials, Government agencies

Priority: Essential
Budget: $150,000
Duration: 1 year

Task 5.2 – Develop design and analysis provisions

Task 5.2.1 – Develop systematic design and analysis processes

Description:

Using the analysis and design methodologies defined in the **SPP** and **NPP**, the team will create design and analysis processes that take a building through concepts into final design, identifying major steps along the way. Procedures will be developed for new and retrofit conditions. The team will develop minimum performance objectives to be included in the standards based on the economic and social drivers developed in the **RMP.** A focus will be on developing modeling guidelines to lend consistency to the design and analysis process. The team will work closely with the verification team in Task 5.3, to ensure that the provisions are tested and are acceptable. This team will be responsible for suggesting refinements or changes to the technical product research as necessary to accommodate the provisions. A goal should be to minimize this as much as possible, to maintain the schedule and budget. The committees will write the provisions using consistent and appropriate language, figures, equation styles, procedures for implementation, etc.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies, (Financial interests)

Priority: Essential
Budget: $1,200,000
Duration: Throughout the project

Task 5.2.2 – Write a technical commentary to support the Guidelines

Description:

The team will write a technical commentary to support the information in the PBSD Guidelines. It will develop the format of the commentary to track the outline of the Guidelines. The goal of the commentary is to give specific background on the development of the procedures within the Guidelines and to explain the concepts in technical terms. It should also contain many references to allow users to obtain additional guidance. The team will consider the